SUMMARY DESCRIPTION OF GRADE NINE SCIENCE OBJECTIVES AND TEST ITEMS

CURRICULUM
EDUCATION LI

(REVISED EDITION)

CURRICULUM GUIDE

Prepared At The Direction Of
HIGH SCHOOL ENTRANCE EXAMINATIONS BOARD
DEPARTMENT OF EDUCATION

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Edmonton, Alberta
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FOREWORD

The first edition of this pamphlet was sent to schools in December, 1964. This revision has incorporated minor changes only.

The June, 1965, final examination in Grade IX Science is secured; that is, all copies of the test, both used and unused, must be returned to the Examinations Branch. In order that teachers might profit from the examination, a supplement to this Summary Description will be issued in the fall of 1965. This supplement will contain items from the June test, and will show the classification of each. There will be a short discussion on each item selected giving information such as why the item was placed in a certain category and how the pupils fared in responding to the item.

It is felt that the supplement will be of more value to the teachers than releasing the paper for sale without comment. It is felt, also, that the new procedure will encourage teachers to teach science for its own sake, rather than for an examination.

SUMMARY DESCRIPTION OF GRADE NINE SCIENCE OBJECTIVES AND TEST ITEMS

This pamphlet consists of three parts: (1) a general introduction (pages 1-7); (2) a blueprint showing the relative emphasis to be placed on content topics and objectives (page 8); and (3) a descriptive classification of objectives and test items (pages 9-24).

The classification of educational objectives is based upon one which was developed by a group of college and university examiners and published as the Taxonomy of Educational Objectives: Cognitive Domain.[1] It is now generally referred to as "Bloom's Taxonomy" after the editor. Bloom and his associates attempted to classify all educational objectives under three domains: cognitive, affective, and psychomotor. They then tried to give precise and usable definitions of each domain with the idea that teachers could formulate objectives according to the three domains. They further believed that the taxonomy in the cognitive domain could be so arranged and developed that learner behaviours related thereto could be classified in a relatively small number of classes. Further, they believed that nearly all classes of behaviour might be observed in any subject matter area at any grade level.

The cognitive domain was defined to include all those objectives which deal with the recall or recognition of knowledge and the development of intellectual abilities and skills. Most of what children learn in reading and arithmetic, for example, and what high school students learn in science, mathematics, English and social studies are learnings in the cognitive domain - knowledge and intellectual skills and abilities.

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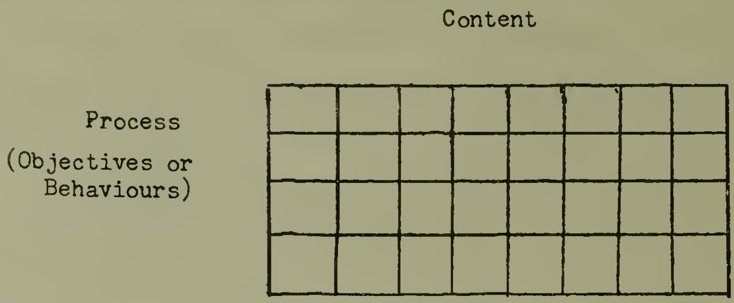
[1] Bloom, B.S. (ed), Taxonomy of Educational Objectives: Cognitive Domain. New York: Longman Green, 1956, 207 p.

Bloom's classification has the advantage of having been extensively discussed and illustrated, particularly in the publication named above.[2] It has one major disadvantage in that the objectives are usually stated in general terms and are not always illustrative of all subject areas. In addition, the items and questions do not always include examples from all subject matter areas. The purpose of this paper is to simplify and adapt Bloom's taxonomy to Grade Nine Science and illustrate it with objectives and items from Grade Nine Science. It should then be a useful guide for classroom evaluation and instruction.

For purposes of test construction the most practical form of analysis of a course of studies is in some kind of grid or blueprint as follows:



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[2] Several adaptations have appeared in recent years. One such attempt was made by the School Mathematics Study Group in the National Longitudinal Study of Mathematical Abilities, another by the Biological Sciences Curriculum Study. (In addition, the 1964 Handbook: Cooperative Science Tests classifies the items in the Cooperative Science Tests series according to Bloom's Taxonomy.

The categories of the "Content" dimension should represent the natural sub-division of the subject matter, for example, the units of the course or adaptations of them. The "process" dimension is represented by various categories of objectives in the case of instruction, and student behaviours in the case of tasks set in test questions. Of course, behaviour revealed by tasks in test questions should parallel instructional objectives.

Bloom's taxonomy of educational objectives in the cognitive domain is an attempt to set out in a logical way the sub-categories of the process dimension. It has first been divided into two broad areas - knowledge, and intellectual skills and abilities. Each of these had been divided and sub-divided as follows:

Knowledge

- Knowledge of Specifics
  - Knowledge of terminology
  - Knowledge of specific facts
- Knowledge of Ways and Means of Dealing with Specifics
  - Knowledge of conventions
  - Knowledge of trends and sequences
  - Knowledge of classifications and categories
  - Knowledge of criteria
  - Knowledge of methodology
- Knowledge of the Universals and Abstractions in a Field
  - Knowledge of principles and generalizations
  - Knowledge of theories and structures

Intellectual Skills and Abilities

- Comprehension
  - Translation
  - Interpretation
  - Extrapolation
- Application
- Analysis
  - Analysis of elements
  - Analysis of relationships
  - Analysis of organizational principles
- Synthesis
  - Production of a unique communication
  - Production of a plan, or proposed set of operations
  - Derivation of a set of abstract relations
- Evaluation
  - Judgments in terms of internal evidence
  - Judgments in terms of external criteria

Such a detailed breakdown is invaluable in question writing and test assembly. However, without a thorough acquaintance with it, it may be too confusing. A streamlined version is, therefore, presented in which only the main categories are included. These are:

KNOWLEDGE

1.1. Knowledge of Specifics

1.2. Knowledge of Ways and Means of Dealing with Specifics

1.3. Knowledge of the Universals and Abstractions in a Field

INTELLECTUAL SKILLS AND ABILITIES

2. Comprehension - Transitional category between Knowledge and Higher Mental Processes.

3. Application)
4. Analysis)
5. Synthesis)
6. Evaluation)

Higher Mental Processes

Each of these eight categories will be illustrated with a variety of objectives and items. Before presenting these illustrations some further discussion of the characteristics of the taxonomy is included.

A taxonomy is a classification scheme for data according to their natural relationship, including their arrangement in a hierarchal order. For example, the first objective is the one which involves the least complex mental ability. In general, successful mastery of the first objective for any subject area is required before a student can demonstrate, for this subject, competence in further objectives from the hierarchy. In other words, a student must know before he can comprehend and he must comprehend before he can apply. The taxonomy can be considered to be hierarchal on more than the one dimension mentioned above, that is, simple to complex. It should be noted that as behaviour becomes more complex the individual is more aware or conscious of his behaviour. Also, roughly paralleling the simple to complex dimension in behaviour is a concrete to abstract dimension in respect to the task presented.

From the testing point of view, it tends to be more efficient to measure the higher categories in the taxonomy because if a person can apply a principle in a new situation he must be able to comprehend the principle and he must also know the principle. On the other hand, a student is more apt to comprehend and even more apt to know the principle. If, in addition, individual differences in ability and achievement are considered, tests should typically sample from all or most categories in the taxonomy.

It is suggested that during the first reading of this taxonomy the teacher should attempt to comprehend only the overall structure described in the immediately preceding paragraphs. Complete understanding of the taxonomy and its application to classroom instruction and measurement will be achieved only after continued use.

The method of classification of behaviour has not resulted in as sharp distinctions between categories as would appear on first reading. As a result several cautions should be observed in applying the taxonomy to classroom practice. First, the distinction between categories, particularly adjacent categories, may not always be completely clear in a specific situation to the novice. It is impossible to provide examples of all the possible objectives or behaviours that fall in a category. A second probelm is that if the method by which the student solves a problem is analyzed, one student may arrive at the answer by memory, the other by applying general principles. In other words, the student's previous experience, particularly how he has been taught, affects the absolute classification of a behaviour. Thus, test items can only be classified on the average, as the typical teacher treats the subject. The purpose of the taxonomy, therefore, is to emphasize the wide range of objectives the teacher should attempt to use and the wide range of behaviour a test should attempt to measure.

The more complex and higher categories of the cognitive domain require far more sophisticated learning experiences than communication of the correct version of an idea, event, or abstraction to the student. Much more participation on the part of the learner is necessary and more opportunities must be provided to help the student gain insight into the processes he uses and misuses if those complex objectives are to be achieved. The lecture method, telling the students what they are to do or how they are to do it, and limited demonstrations of appropriate problem solving processes are not very effective in bringing about competence with the higher categories of the taxonomy. The entire course must be turned toward the achievement of complex objectives if they are to be attained in any significant way or degree. This emphasis will not result in any loss in achievement of the knowledge objectives.

In order to maximize effectiveness of student achievement of the complex higher objectives the teachers should develop the central unifying ideas of the physical sciences, stress precise and accurate definition, emphasize similarities and differences between related concepts and abstractions, and have students reformulate new propositions in their own words. Teachers can foster the thinking involved in the complex objectives by using them. For example, encourage students to recognize and challenge assumptions underlying new propostions, have them distinguish between facts and hypotheses or between warranted and unwarranted inferences.

Table 1 (page 8) shows the intended approximate proportion of marks that were assigned to each category of the taxonomy and to each content topic for the June 1965 Grade Nine Science Examination.

The discussion to this point and the illustrations of test items to follow show that multiple-choice items can be very penetrating and thought-provoking. The best way to prepare students is to teach science for science's sake and not to try to outguess the examiners. On the other hand it might be worthwhile cautioning students that careful thought should be given to each question before an answer is selected. Some questions have two or more alternatives that are not entirely wrong, but one of the alternatives is clearly better than the other. To find this answer requires thought; looking for familiar catch words or phrases is no substitute. Students should have ample experience in class with both objective and essay questions that measure a wide variety of objectives.

Blueprint Of Grade Nine Science Examination, 1965

OBJECTIVES	Topic or Content Area									Emphasis %
	Matter and Energy Force, Work & Power	Mechanics		Chemical Reactions	Heat	Light	Trans-portation	* Measurement	Science* as Inquiry	
		Machines	Fluid							
1. KNOWLEDGE										40
2. COMPREHENSION										30
3 APPLICATION										20
4, 5, and 6 — ANALYSIS, SYNTHESIS AND EVALUATION										10
Emphasis %	5	15	5	15	15	15	10	5	15	100

* Note: The topics "Measurement" and "Science as Inquiry" cut across Content Areas. The latter category will be used for items that involve more than one content area or that involve inquiry as, for example, Items 6 to 10 under Analysis.

KNOWLEDGE

The objectives falling under knowledge require remembering - either by recall or recognition - material previously studied. Usually some reorganization or alteration of the material is required as the items or questions should not be posed in a form identical to that presented in the textbook or lecture. The difficulty of the items is determined primarily by the amount or complication of the information that must be remembered. The abilities in this area fall into three categories: 1.1. Knowledge of Specifics, 1.2. Knowledge of Ways and Means of Dealing with Specifics, and 1.3. Knowledge of Univerals and Abstractions in a Field.

1.1. Knowledge of Specifics

Objectives falling in the category entitled Knowledge of Specifics include knowing terms and their symbols and knowing discrete isolated facts, such as dates, persons, places, and findings which are essential for purposes of communication and for thinking about specific problems.

Some Objectives[3]

1. Defines terms and concepts in science such as energy, molecule, kilogram.
2. Recognizes meaning of symbols, for example, H_2O
3. Recalls specific physical and chemical properties of common elements and compounds such as oxygen, carbon dioxide, and water.
4. Recognizes dates, events, and names of scientists associated with such events, such as the invention of the electric light bulb by Edison in 1879.

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[3] In all categories of the taxonomy, supply type items (completion, short answer, short and long essay) can be made by rewording the objectives. In the lower categories of the hierarchy the items will be of the completion or short answer type, then as one moves into the intellectual skills and abilities, they will be predominantly of the short or long essay type.

Some Items [4]

1. The name given to ANY device which helps to do work or transfers energy is a

    A. lever
    *B. machine
    C. pulley
    D. screw
    E. wedge

2. The symbol which represents an atom of iron is

    A. Ca
    B. Cu
    C. Na
    *D. Fe

3. The percentage of oxygen in the atmosphere by volume is approximately

    A. .04%
    B. 1%
    C. 4%
    *D. 21%
    E. 78%

1.2. Knowledge of Ways and Means of Dealing with Specifics

Knowledge of Ways and Means of Dealing with Specifics includes knowing the methods of experimentation, and the ways of studying, organizing, judging, and criticising ideas and phenomena. Science has a body of techniques, criteria, classifications and forms which are used to discover specifics as well as to deal with them once they are discovered. Knowledge of Ways and Means can be distinguished from Knowledge of Specifics by several characteristics. Ways and Means refers to processes rather than to products. It indicates operations rather than the results of operations. It includes knowledge which is largely the result of agreement and convenience rather than the knowledge which is more directly a matter of observation, experimentation, and discovery. It more commonly reflects how workers in the field think and attack problems rather than the results of such thought or problem solving. Also the abilities classified under ways and means do not involve the actual use of ways and means but only that the student be aware of their existence and possible use. The actual skills and abilities involved in their use are described in the categories under Intellectual Abilities and Skills.

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[4] The correct answer is starred, for example, *B.

Some Objectives

1. Recognizes when precision of measurement given is of a degree warranted by the nature of the problem. For example, the rule for "rounding off" numbers.
2. Recognizes casual interrelations of a series of specific events such as which valve is open when the piston of a lift pump is moving downwards.
3. Recalls nature of process, for example, change in energy involved when water evaporates.
4. Recalls or recognizes classifications which structure and systematize physical and chemical phenomena such as types of energy or classes of compounds.
5. Knows criteria for judging the adequacy of an experiment.
6. Knows the procedure for the laboratory preparation of oxygen or the destructive distillation of coal.

Some Items

1. Magnetic Poles are usually named

A. + and -
B. red and blue
*C. north and south
D. anode and cathode

2. Bringing a car to a stop by applying the brakes represents a change of

A. potential energy to kinetic energy
B. potential energy to heat energy
C. kinetic energy to potential energy
*D. kinetic energy to heat energy
E. heat energy to kinetic energy

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Items 3 - 6 involve simple machines. For each item select from the key the type of machine it illustrates.

3. Ramp
4. Block and tackle
5. Human arm
6. Rotary egg beater

KEY

A. Lever
B. Inclined plane
C. Pulley
D. Wheel and axle
E. Screw

(Keyed answers are: 3 (B), 4 (C), 5 (A), 6 (D).)

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7. A steam turbine is usually more efficient than a reciprocating type of steam engine chiefly because in the steam turbine

*A. greater expansion of steam occurs
B. there are fewer different moving parts
C. no condenser is needed
D. all motion is rotary rather than partly back and forth
E. very high operating speeds are possible

8. When oxygen is prepared in the laboratory it is collected by

A. the upward displacement of air
B. the downward displacement of air
C. the upward displacement of water
*D. the downward displacement of water

9. When the scientist is confronted with a problem, his first step toward solving it should usually be to

A. construct or purchase equipment
B. perform an experiment
C. draw conclusions
D. urge other scientists to cooperate with him in working it out
*E. gather all available information on the subject.

1.3 Knowledge of Univerals and Abstractions

Knowledge of Universals and Abstractions includes the knowledge of the major schemes and patterns by which phenomena and ideas are organized. These are the larger structures — the theories, principles and generalizations — which dominate physics and chemistry or which are quite generally used in studying phenomena and solving problems.

Principles, generalizations and theories bring together a larger number of specific facts and events, describe the processes and interrelationships among these specifics, and thus enable the scientist to summarize and organize phenomena. These concepts are rather difficult for a student to understand. However, once they are acquired he has a means of relating and organizing a great deal of subject matter and as a result should have more insight into the field as well as greater retentiveness for it.

Some Objectives

1. Recalls Newton's Third Law of Motion.

2. Recognizes the relationship between volume and pressure when temperature is changed.

3. Knows the interrelationship among several principles or theories, for example, energy is involved in both mechanical work and radiant heat.

Some Items

1. If the volume of a given mass of gas is kept constant, the pressure may be diminished by

   *A. reducing the temperature
   B. raising the temperature
   C. adding heat
   D. decreasing the density
   E. increasing the density

2. Archimedes' principle states that

   A. the pressure at any point in a liquid is equal in all directions
   B. pressure applied to a condined liquid is transmitted equally throughout the liquid
   C. water will rise in a capilliary tube in a height such that the surface tension is balanced by the weight of the water elevated
   D. the pressure at any depth in a liquid is measured by the product of the height and the density of the liquid
   *E. a body displacing any amount of fluid is buoyed up by a force equal to the weight of fluid displaced

3. Which helps to explain the lifting power of an airplane in motion?

   A. the momentum of a body increases with its velocity
   B. the acceleration of gravity
   *C. a force acting on a surface at an angle may be resolved in two components
   D. the buoyancy of a body is equal to the difference between the weight and that of the displaced air

INTELLECTUAL ABILITIES AND SKILLS

Bloom has grouped all the remaining categories in the taxonomy under Intellectual Abilities and Skills. These refer to the organized modes of operation and generalized techniques for dealing with problems and materials. The materials and problems may be of such a nature that little or no specialized and technical information is required. Such information as is required can be assumed to be part of the individual's general fund of knowledge. Other problems may require specialized and technical information of a rather high level such that specific knowledge and skill in dealing with the problem and materials are required. The abilities and skills objectives emphasize the mental processes of organizing and re-organizing material to achieve a particular purpose. The materials may be given in the item or remembered.

It may be more convenient, in order to achieve greater comprehension of the taxonomy, to divide Blooms' Intellectual Abilities and Skills in two categories: Comprehension and Higher Mental Processes. The latter category, Higher Mental Processes, would include: 3. Application, 4. Analysis, 5. Synthesis, and 6. Evaluation. The reason for doing this is that comprehension represents a low level of understanding. Also, when testing for Comprehension the student is usually put into a situation parallel to that discussed in class or text and asked to demonstrate that he comprehends or understands the material in addition to knowing it. Whereas, in measuring the higher mental processes the student is usually placed in a new or novel situation and must not only apprehend the material but make use of it.

2. Comprehension

As mentioned above the category called comprehension represents the lowest level of understanding. It refers to a type of understanding or apprehension such that the individual knows what is being communicated and can make use of the material or idea being communicated without necessarily relating it to other material or seeing its fullest implications. It can be considered a transitional category between simply remembering and using mental processes in novel or new situations. This is the intellectual ability (excluding knowledge) most emphasized in school.

The term comprehension includes those objectives which represent an understanding of the literal message contained in a communication. To understand, the student must change the communication in his mind or in his overt responses to some paralle form more meaningful to him. There may be responses which represent simple extensions beyond that which is given in the communication itself.

Some Objectives

1. Illustrates or gives an example, not taken in class, of a principle, for example, the Bernoulli principle.
2. Translates relationships expressed in symbolic form, including illustrations, maps, tables, diagrams, graphs, and mathematical or other formulae to verbal form and vice versa.
3. Distinguishes among warranted, unwarranted or contradicted conclusions drawn from a body of data.
4. Makes proper qualifications when interpreting data.
5. Determines the implications, consequences, corollaries or effects in an experiment.
6. Predicts trends and interpolates data.

Some Items

1. 81 calories is the amount of heat necessary to

   A. raise the temperature of 1 gram of ice from -1 degree C to 0 degrees C. (The ice is not melted in the process.)
   B. raise the temperature of 80 grams of water 1 degree C.
   C. raise the temperature of 1 gram of water 1 degree C.
   *D. raise the temperature of 1 gram of ice from 0 degrees C to water at 1 degree C.
   E. melt 81 grams of ice.

2. If a force is moved a short distance and the resistance is moved a greater distance without friction, the machine that illustrates this principle is the

   A. door knob
   B. brake pedal
   *C. tweezers
   D. light switch

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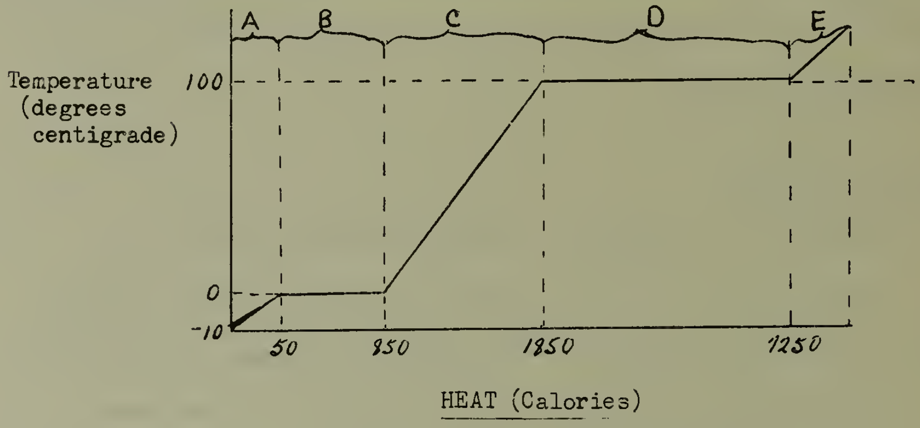
The relationship between the addition or removal of heat and the consequent changes in the temperature and physical state of 10 grams of water may be represented schematically as follows:



For Items 3 to 5 select the portion of the curve in the diagram labelled from A through E that illustrates

3. the heat of fusion.

4. the heat of vaporization.

5. the volume change that is greatest.

(Keyed answers are: 3 (B), 4 (D), 5 (E).)

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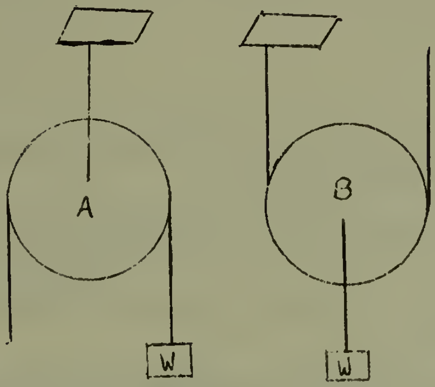
6. In the diagram below, the theoretical mechanical advantage of machine A is

   A. equal to that of B
   B. twice that of B
   *C. one-half that of B
   D. many times that of B
   E. only a very small fraction of that of B.



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3. Application

Application can best be described by comparing it with comprehension. A problem in the comprehension category requires the student to know an abstraction well enough that he can correctly demonstrate its use when he is specifically asked to do so. Application, on the other hand, requires a step beyond this. Given a problem new to the student, he will apply the appropriate abstraction without having to be prompted as to which abstraction is correct or without having to be shown how to use it in that situation. In comprehension the student shows that he can use the abstraction when its use is specified. In application the student shows that he will use the abstraction correctly given an appropriate situation in which no mode of solution is specified.

It is not necessary always to require a complete solution. Sometimes a partial solution or selection of the correct abstraction alone is requested. In all cases, however, the task should use material the student has not had contact with, or take a new slant on common material or use a fictional situation. If the material is familiar, comprehension or recall is required, not application.

Some Objectives

1. Applies scientific concepts and principles used in class to the phenomena discussed in a paper.
2. Predicts the probable effect of a change in a factor on a chemical solution previously at equilibrium.
3. Applies scientific principles, postulates and other abstractions to new situations.
4. Finds solutions to problems in making home repairs employing experimental procedures from science.

Some Items

1. What effect would an increase in pressure in the boiler of a steam engine have upon the performance of the steam engine?
2. A baseball can be made to curve. How can this be explained?
3. Would the air in a closed room be heated or cooled by the operation of an electric refrigerator in the room with the refrigerator door open?

*A. heated, because the heat given off by the motor and the compressed gas would exceed the heat absorbed.
B. cooled, because the refrigerator is a cooling device.
C. cooled, because compressed gases expand in the refrigerator.
D. cooled, because liquids absorb heat when they evaporate.
E. neither heated nor cooled.

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Items 4 and 5 are based upon the following situation.

The boiling and freezing points of water were determined and marked on the glass of a new, and as yet "blank" thermometer. If these two points are 9 inches apart, how far apart would the degree markings be if it were desired to make

4. A Centigrade therometer?

   A. 9/180 inch
   *B. 0.09 inch
   C. 0.9 inch
   D. 9/16 inch
   E. 9/32 inch

5. A Fahrenheit thermometer?

   *A. 0.05 inch
   B. 0.5 inch
   C. 0.09 inch
   D. 9/100 inch
   E. 9/32 inch

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6. An automobile weighing 3,300 lbs. goes up a hill 160 ft. high in 20 secs. The output of the motor in horsepower must be

   A. 8
   *B. 48
   C. 412.5
   D. 10,560,000

Note: Item 6 should be classed as "Comprehension" if it is parallel to, or similar to items taken in class. In Items 4 & 5 the situation is probably novel - it has a new twist. Item 6 might be made novel to most students, for example, by including the length of the hill.

4. Analysis

Analysis is related to both comprehension and evaluation. In comprehension the emphasis is on the grasp of the meaning and intent of the material. Analysis emphasizes the breakdown of the material into its constituent parts and detection of the relationships of the parts and of the way they are organized. It is also sometimes directed at the techniques and devices used to convey the meaning or to establish the conclusion of the communication. Comprehension deals with the content of the material alone, analysis with both content and form. On the other hand, evaluation involves more than analysis or even critical analysis in that, when one evaluates, in addition to analyzing a judgment is made in terms of some criteria as to its adequacy.

Some Objectives

1. Recognizes unstated assumptions.
2. Distinguishes facts from hypotheses.
3. Distinguishes conclusions from statements which support it.
4. Checks consistency of hypotheses with given information and assumptions.
5. Distinguishes cause and effect relationships from other sequential relationships.
6. Detects the purpose, point of view, attitude, or general conception of the author.

Some Items

1. "Light is produced indirectly in the fluorescent lamp." What would be another way of expressing the conclusion implied in the above statement?

2. 1 liter = .88 qt. Are there more quarts than liters in a container whose capacity is 1000 cc?

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Item 3 contains a pair of statements which are either in agreement with each other or not in agreement, and either of the statements may be true or false. Study the pair of statements and choose

A. if statements I and II are in agreement and both false.
B. if statements I and II are in agreement and both true.
C. if statements I and II are not in agreement; I true, II false.
D. if statements I and II are not in agreement; I false, II true.

3. I. At absolute zero the molecules of a substance do not move with respect to each other.

   II. No heat energy is possessed by a substance at absolute zero.

   (Key: (B) Note: This pair of statements is only illustrative as other pairs of statements could be added to make use of the same alternatives.)

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The following paragraphs concern the action of a geyser. Read the passage carefully before answering Items 4 - 8 inclusive.

A geyser is a hot spring that erupts at intervals. It is made up of a more or less crooked or constricted, tubular fissure that extends into the earth and is filled with water. A source of heat near the bottom of the fissure heats the water.

After an eruption the tube fills with water from an underground source. The water throughout most of the length of the tube, and especially in the lower part, becomes heated to a point above the normal boiling temperature (212°F.) of water but does not become quite hot enough to turn to steam. However, sooner or later, some of the water in the lower part of the tube at the source of heat reaches the boiling point and turns to steam. The steam raises the whole column of water above it and causes some water to overflow from the geyser pool at the surface. This overflow acts as a trigger, permitting the whole column of water in the tube to flash into steam which blows from the fissure in an eruption.

For each of Items 4 - 6 choose

A. if the statement is true and pertains directly to the action of the geyser.
B. if the statement is true but is not directly concerned with the action of the geyser.
C. if the statement is false.

4. If the tube were not crooked and constricted the water throughout the tube would come to nearly the same temperature by unrestricted convectional circulation, the water would boil, and a boiling spring rather than a geyser would result.

5. The boiling point of water in the bottom of the tube is lower than it is at the top.

6. The water in the tube does not turn to steam although it is above the normal boiling point because of the pressure of the overlying water.

(Keyed answers are: 4 (A), 5 (C), 6 (A).)

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7. Air pressure on a fine day is usually higher than on a stormy day. Thus, the geyser will erupt more often during stormy weather. This statement can best be evaluated as

A. a wild guess.
*B. true, because it can be predicted from known principles.
C. false, because it cannot be predicted from known principles.
D. true, because it is based on statements in the above passage.
E. false, because it contradicts the statements in the above passage.

8. An investigation of which one of the following hypotheses concerning the boiling point of water is most suggested by the observation of a geyser?

   A. the boiling point of water decreases with increasing altitudes.
   B. the boiling point of water is that point when the vapor pressure equals the atmospheric pressure.
   *C. the boiling point of water in a pressure cooker is above 212 F.
   D. the boiling point of water in a hot water heating system is above 212° F.

   (Note: Item 4. is classified as Analysis, 5. as Knowledge of Specifics, 6. as Comprehension, 7. as Evaluation, and 8. as Synthesis.)

5. Synthesis

Synthesis emphasizes the putting together of elements and parts in such a way as to constitute a pattern or structure not clearly there before. Generally this involves a recombination of parts of previous experience with new material reconstructed into a new and more or less well-integrated whole. This is the category in the cognitive domain which may not always be free creative expression since generally the student is expected to work within the limits set by particular problems, materials, or some theoretical or methodological framework.

Some Objectives

1. Describes an original experiment conducted by a student.
2. Proposes ways of testing an hypothesis.
3. Integrates the results of an investigation into an effective plan or solution to solve a problem.
4. Develops schemes for classifying chemicals.
5. Formulates hypotheses to explain adequately a wide range of seemingly interrelated phenomena and be internally consistent.
6. Makes deductions from basic theories.

Some Items[5]

1. How could you construct an oil barometer from oil which floats on water?

2. Given:
   1. Work = fd.
   2. Power is work per unit of time.
   3. 33,000 ft. lb. per min. = 1 H.P.

   Develop the formula for Horsepower H.P. =

3. You suspect that a certain soluble compound contains hydrogen. Which of the following would be a way of checking your suspicion?

   A. prepare a solution of the compound and subject it to electrolysis, using Hoffman's apparatus.
   B. place a sample of the compound in a Bunsen flame and determine if any water vapor is produced.
   C. heat the compound to incandescence and analyze the light produced with a pyrometer.
   *D. vaporize some of the material in a flame and use a spectroscope to analyze the light produced.
   E. pass some light through a solution of the compound and analyze the spectrum produced with a spectroscope.

4. See also Item 8 under Analysis.

6. Evaluation

Evaluation includes the process of making judgments concerning the extent to which ideas, solutions, methods, and material satisfy criteria. It involves the use of criteria as well as standards for appraising the extent to which particulars are accurate, effective, economical or satisfying. The judgments may be either quantitative or qualitative and the criteria may be either those determined by the student or those which are given to him.

Some Objectives

1. Detects the logical fallacies in arguments.

2. Discerns the inconsistencies and/or logical inaccuracies in data.

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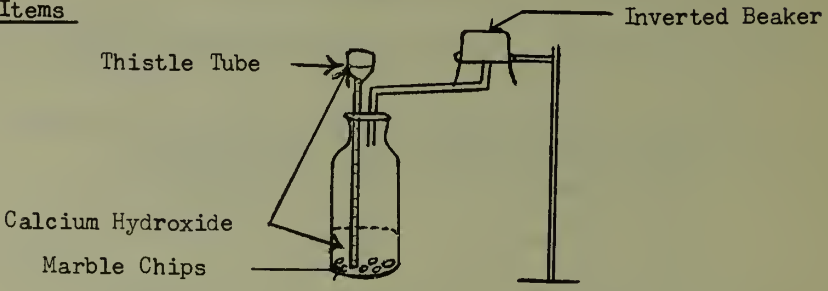
[5] It is extremely difficult to write objective items to measure synthesis and evaluation. Bloom provides several examples in science. The Physical Science Study Committee tests published by Educational Testing Service also have examples.

3. Identifies the procedural errors in an experiment and evaluates their effect on the results.

4. Compares the effectiveness of a method used to solve a problem with the best possible method available.

5. Identifies additional evidence or experimentation that is necessary to fully justify the conclusions reached.

Some Items



The above apparatus was set up to prepare carbon dioxide. The contents of the inverted beaker were tested with lime water which did not turn milky. It was concluded that the calcium hydroxide solution was not strong enough.

1. What logical inconsistencies are there in the report of the experiment?

2. Identify the procedural errors in the experiment and evaluate their effect on the results.

3. A recent popular article stated that, if a space craft were being rocketted away from the surface of the earth fast enough, its speed would offset the pull of gravity and a man in the rocket would feel weightless. This statement should be evaluated as being

   A. accurate since two forces are involved in the described situation and two forces can offset one another.
   B. accurate since the weight of an object decreases rapidly as the distance from the center of the earth decreases.
   *C. inaccurate since the floor of the man's compartment will be pushing up on the man as the rocket rises, and this push will give a feeling of increased rather than decreased weight.
   D. inaccurate since no object within the gravitational field of the earth can be weightless and so cannot seem weightless
   E. inaccurate since the chance that the force on the man due to the rocket moving up and the force of gravity pulling the man down will be equal is extremely minute.

4. See also Item 7 under Analysis.

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